

1. INTRODUCTION

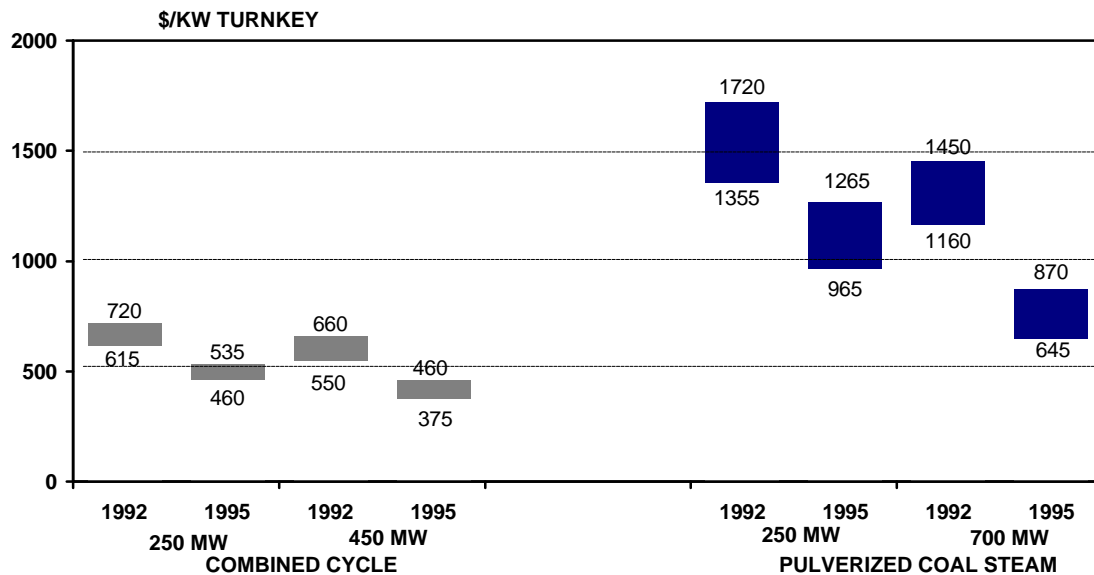
As deregulation unfolds and privatization of the utility market takes shape, priorities for power plant economics have shifted toward those of a “bottom-line” business and away from a regulated industry. Competition in utility generation and the exposure risks of large capital investments have led to a preference to minimize capital costs and fixed and variable operation and maintenance costs. With global competition from independent power producers (IPPs), non-utility generators, and utilities, the present trend of investments is with conventional pulverized coal and natural gas-fired power plants, which can be brought on-line quickly at minimum cost.

Aligned with these trends, the power plant investor is oriented toward highly reliable, modular designed power plants that can be brought on-line quickly, comply with emissions requirements, and support both base load and dispatch operation. In addition, a top priority is placed on flexibility in both fuel and operations. This places a premium on technologies that can operate on multi-fuels with minimum sacrifice in performance, availability, and efficiency. Flexibility in operation is related to load-following capability as the investor seeks to recover capital in a market becoming dominated by low-cost providers.

Dramatic improvements in the economics of the pulverized coal (PC) and the natural gas combined cycle (NGCC) power plant over the last decade have occurred in response to the concerns of the decision-maker in assuring the financial success of power projects, as illustrated in Figure 1-1. During the 1980s through the 1990s, commercially supplied PC plants with flue gas desulfurization (FGD) with nominal capacities of 500 MWe were priced in the mid \$1,300 per kWe (1995\$). Presently, the total plant costs (TPC), which are essentially overnight construction costs, for U.S. plants can be commercially offered for under \$1,000 per kWe. Technology and economic advancements contributing to this reduction can be summarized by the following categories:

- Performance Improvements
- Plant Automation and Reliability Improvements
- Direct Equipment Cost Reductions

Figure 1-1
DECREASING COSTS FOR PULVERIZED COAL AND NATURAL GAS



SOURCE: CAMBRIDGE ENERGY RESEARCH ASSOC.

- Reduced Construction and Startup Schedule
- Increased Market Competition

Circulating pressurized fluidized-bed combustors (CPFBC) and integrated gasification combined cycles (IGCC) coal-based electric power generation systems are now in demonstration under the U.S. Department of Energy's (DOE) Clean Coal Technology (CCT) Program. Despite the performance and emission advantages of these technologies, high capital costs threaten competitiveness in the utility market. As a result, it is critical to determine if the same improvements in capital cost experienced by the pulverized coal technology can be achieved by these advanced power generation technologies.

1.1 OBJECTIVE AND APPROACH

The objective of the work discussed in this report is to provide economic data and supporting analyses in determining commercially mature costs for clean coal technologies through evaluation and correlation to the cost improvement trends of the state-of-the-art PC and gas turbine power plants. Key issues include:

- Development of market-based economics for advanced coal-based technology.
- Application of innovative methods to reduce capital cost while maintaining plant availability.
- Reduction of capital and indirect costs through shorter construction periods and lower interest during construction.
- Application of advanced gas turbine technology from DOE's Advanced Turbine System (ATS) program.

The approach to determine market-based costs for IGCC and CPFBC technologies included:

- Establishment of cost changes in PC plants experienced since the implementation of New Source Performance Standards (NSPS) Subpart Da (Electric Utility Steam Generating Units for which Construction Commenced after September 18, 1978).
- Definition of the base-line economic data for the early commercial offerings for IGCC and CPFBC from information developed from DOE's CCT program.
- Identification of IGCC and CPFBC process and generation systems that are expected to mature through CCT demonstration and commercial application through the year 2015.
- Application of cost improvements in process and generation, which can be expected for commercially mature IGCC and CPFBC technologies from correlation to the evolution of the PC plant.

1.2 BACKGROUND

Competition in utility generation and the risks of large capital investments have led to a preference to minimize both capital costs and fixed and variable operation and maintenance costs. Many of

the issues confronting the decision-maker when selecting technology options are tied to evaluating a project's economic risk. Economic issues include those directly related to capital and fixed operating cost, such as equipment or process availability, economy of scale, construction, and startup schedule, just to name a few. The PC plants of the 1990s have experienced increases in thermal and emission performance at lower capital and production cost compared to plants a decade earlier. Both process and generation improvements contributed to this evolution. Examples of these include:

- Performance Improvements

During the 1970s and 1980s new steam plant efficiencies remained in the 36 to 39 percent range with average system pressure at 2400 psig and single reheat at 1000°F. Increases in plant power consumption occurred due to the additional environmental control equipment including FGD and larger precipitators. These parasitic loads were in addition to the effects of widespread adoption of evaporative cooling towers as heat sinks, which replaced the once-through cooling used on older power plants. The combined effects of these measures contributed to a virtual freeze on steam power plant thermal efficiencies that lasted for over three decades.

The 1990s have brought about increasing thermal efficiencies as a result of improvements in steam turbine performance, lower auxiliary loads for environmental control systems, and performance optimization through automated controls.

- Plant Automation and Reliability Improvements

Integrated automation and data access systems are achieving lower electrical production costs through optimizing plant performance and reliability while meeting dispatch and environmental constraints. Typically, plant automation involves:

- Upgrades to higher accuracy instruments
- Performance improvement through the plant's distributed control system (DCS) providing on-line plant performance calculations, heat rate, and operator controllable losses

- Operator interface with real-time information for immediate performance
- Access to plant-wide information to balance operational parameters including dispatch, emission compliance, and efficiency.
- Direct Equipment Cost Reductions

With the development of more reliable components and the need to lower capital investments, PC plants are now designed with fewer redundant or reduced capacity components, while achieving high availability client standards. As an example, the reduction in cost for FGD has been significant, from over \$220 per kWe to under \$125 per kWe in the last 10 years. This decrease is directly related to the developments in performance improvements through increased sulfur capture, better process control and availability, the elimination of absorber redundancy, and reduction in supporting equipment redundancy.

- Reduced Construction and Startup Schedule

Construction and startup schedules typical to the PC plant just five years ago could extend beyond four or five years. With today's competitive influence of reducing up-front costs and funds during construction, these same plants are experiencing construction schedules of less than three years. Engineering techniques, which include parallel design and field erection, partnering between owners and suppliers, and enhanced computer aided design capability, provide the tools necessary to shorten construction and startup.

- Increased Market Competition

In response to these market and regulatory changes, the power generation sector has begun aggressive restructuring, mergers and acquisitions, and the development of lower cost power generators. The baseline for comparison is the existing generators on the grid selling power. From the perspective of the power generator owner, the economics of the project are fundamental to the success of the project in that the financial community is looking for a reasonable return on investment.

1.3 REPORT OVERVIEW

The design basis for the generation evaluations is presented in Section 2, including site and coal characteristics and plant configurations. The performance, environmental, and cost data developed for this evaluation are the result of maintaining a consistent design basis throughout. Common design inputs for site, ambient, and fuel characteristics were used for each technology under consideration. Power plant configurations were identified to fit the expected load demand for the years 2005 to 2010.

Section 3 provides a technical description and costs for the market-based pulverized coal power plants including subcritical, supercritical, and ultra-supercritical. Cost improvements in PC plants experienced since the implementation of NSPS Subpart Da (Electric Utility Steam Generating Units for which Construction Commenced after September 18, 1978) are defined for key equipment areas.

First-of-a-kind (FOAK) configuration, performance, and costs for IGCC are presented in Section 4. As this technology is in its demonstration phase of commercial development, cost and performance data were defined on the basis of existing data modified to determine expectations for early commercial offerings.

Three advanced IGCC concepts, which are expected to mature through CCT demonstration and commercial application through the year 2020, are also presented in Section 4. Hot gas cleanup systems, including particulate removal and desulfurization, for IGCC have been reviewed for sensitivity to capital cost, operating cost, and cost of electricity against operating parameters. These data, together with other key components such as the advanced gas turbine, are defined as to baseline plant design and cost figures.

A third advanced coal-based power plant concept using CPFBC technology is presented in Section 5. Initial generations of the CPFBC technology have undergone demonstration in the CCT program. Advanced generations are expected to mature through an existing CCT demonstration program with Lakeland Electric & Water that was initiated in 1998 and subsequent commercial applications through the year 2020.

Section 6 provides a technical description and costs for two market-based NGCC power plants. This technology is presented as a benchmark upon which decision-makers base comparisons between natural gas and solid fuel systems.

One of the technology advancements taking place in the power generation industry is in the area of process and equipment control. Its impact is resulting in significant capital cost reductions, improved performance and reliability. A discussion on the advancement in instrumentation and controls is presented in Section 7.

Issues including licensing and environmental overview; air quality, water resources, and solid waste considerations; and potential regulatory impacts are addressed in an overview format in Section 8. A regulatory timeline is provided to demonstrate the relationship between coal-based power generation performance and cost, and emission requirements.

Capital cost and economic comparisons are provided for all generation technologies in Section 9. Market-based economics are established on the basis of project financing and return on investment criteria.

Appendices A and B provide an overview of data collected to establish the cost and performance improvements for supercritical PC and atmospheric fluidized-bed combustion power plants, respectively. Appendix C provides a similar review for the NGCC power plant. Appendix D contains information on the reliability and availability of market-based power plants versus conventional regulated utility power plants. Appendix E includes supporting cost data for each power plant described in this report.

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